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INFRARED SIMULATION AND THERMO-VACUUM FACILITY - ISA/TVA

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ABSTRACTS

A test facility was designed in which the shroud temperature can be continuously variated between 100 $^{\circ}$ K and 363 $^{\circ}$ K by using gaseous nitrogen.

Introduction

The designation "Infrared Simulation and Thermo-Vacuum facility" is misleading, because the infrared radiation is in most cases not produced by the facility itself, but by devices designed specifically for each test specimen.

By the time the test requirements were specified, there remained little time available for preparation of the facility. An available vacuum chamber, previously used for the third stage of the ELDO II launcher, was modified by the addition of a shroud and a thermal system. The vacuum system was improved by the addition of oil-free high-vacuum pumps.

Test Facility Requirements

The HELIOS test requirements for the facility are tabulated in Fig. 2. Two different test methods had to be considered - heater tapes and canister - requiring an uneven heat flux distribution over the shroud. When heater tapes are used, with a shroud temperature of 100°K, the middle section must absorb 25 kw and the upper and lower sections 7.5 kw each. For economical reasons (lower L-N_2 consumption), the option of operating at room temperature that portion of the shroud adjacent to the canister has been provided for.

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The thermal system was designed to allow thermo-vacuum testing from 203°K to 363°K, because no other facility for testing the full-size HELIOS models is available.

For economical reasons one single-phase thermal system using gaseous nitrogen was chosen instead of a two-phase system or one using two cooling fluids; it could be more quickly constructed. The system was built in 14 months - technical problems were reduced by using one refrigeration fluid.

A clean vacuum, less than 1 x 10^{-5} torr during heating of the test specimen, and as free as possible from hydrocarbons, must be guaranteed to protect the extremely sensitive HELIOS experiments.

F a c i l i t y   S y s t e m s

Thermal System

The thermal system consists of two parallel circuits that can be independently controlled (Fig. 3). One circuit cools the middle shroud section and is capable of absorbing 25 kw at 100°K. The other circuit cools the top and bottom sections, capable of absorbing 7.5 kw each. This load distribution was chosen to accommodate the planned specimen mounting position, using the heater tape method mentioned previously.

The refrigeration fluid is gaseous nitrogen, circulated by a Roots blower. The heat of compression is mostly dissipated by the water-cooled blower jacket and the subsequent gas chiller. From there the gas passes through a large counterflow heat exchanger, where it is cooled to about 109°K by the gas returning from the shroud. Next, in the injection cooling chamber, the gas is cooled to 95°K by a spray of liquid nitrogen. Before the gas reaches the shroud, it passes through an electric heater which is turned on for chamber warm-up or tests over room temperature. In the shroud the gas absorbs heat and is returned to the blower, after bleeding to atmosphere an amount equivalent to that injected. The efficiency of the single-phase system is mostly determined by the efficiency of the large heat exchanger, which allows the gas temperature to jump from 109°K to 285°K. In addition to the enthalpy of L-N_2 vaporization, the enthalpy difference between the temperature of vaporization and the temperature at which the gas leaves the system (285°K) contributes to the system efficiency. The high temperature of the gas input (285°K) allows the use of ordinary high-capacity Roots blowers. Also the relatively high friction losses associated with gas blowers can be dissipated by water cooling. Variation of the injection rate and turning on the heater allows adjustment of the shroud temperature to any value between 1oo°K and 363°K.

To reach the required temperature of 100°K ± 7,5°K under 40 kw load, 20,120 kg/h of gas must be circulated. This high flow rate requires large pipe cross-sections, achieved with special profiles (Fig. 4).

The top section of the shroud (chamber lid) is a double spiral using counterflow to achieve the most even temperature distribution. The cylindrical section is built up of rings with single or double feed according to load. Because of the vacuum pumps on the chamber floor, the floor shroud is constructed as a baffle to increase its conductivity.

The temperature control system is worth mentioning, because of its simplicity.
The gas temperature is maintained at the chosen value by a TIC regulator (1), which controls the injection rate.
The pressure difference between shroud input and output is held constant by a PIC regulator (2), which controls a by-pass (3).
To compensate for load variations in the 9 sections of the shroud, output valves for each section (4) can vary the flow. These valves are manually operated from the control room.
A third regulator (5) maintains a constant pressure in the system by controlling the bleeder.

The Roots blowers are endangered at temperatures below 273°K. A by-pass (6) between blower output and input can be activited to raise the input temperature; this is only needed when shroud temperature is changed. At lower heat loads, the thermal system can be driven by one blower only (Fig. 3).

The control system is a compromise between automatic and manual operation. The operating point is set manually and held constant by the automatic regulators. The system is simple enough to be operated by two persons; experience has shown that the system is exceptionally trouble-free.

Vacuum System

The unmodified chamber already had a pump system consisting of two mechanical backing pumps and two oil diffusion pumps.

Two additional oil-free high vacuum pumps were installed because surface contamination, especially of the flight unit, is a great danger to the success of the HELIOS mission. They are: a titanium sublimation pump with a high pumping rate, and an ion getter pump which evacuates chiefly the noble gases.

In operation, the oil diffusion pumps are used for preevacuation until a high vacuum is reached at which the titanium sublimation pump and the ion getter pump can function; at this point, the valves between the diffusion pumps and the chamber are closed, and the oil-free high-vacuum pumps take over.

The construction of the high vacuum system is shown in Fig. 6. Ten titanium melting crucibles, in which the metal is vaporized by electron bombardment, are located in the bottom flange of the chamber. The vaporized metal condenses onto the adjacent L-N_2-cooled pump surface. A pumping rate of about 200,000 l/sec is achieved at a pressure of less than 10^{-6} torr.

The ion getter pump consists of 28 elements with a pumping rate of 110 l/sec for each element.

The pumps are mounted on the chamber floor because there the operation is most effective.

Performance and Consumption Data

The operational costs are mostly due to consumption, chiefly if liquid nitrogen.

About 5000 kg of L-N_2 are required to cool the chamber from room temperature to 100°K. Steady operation at this temperature uses about 950 kg/h of L-N_2 at 4 kw heat load, and about 1450 kg/h at 40 kw load. At 203°K and 3 kw load the L-N_2 consumption is about 600 kg/h. To raise the temperature from 203°K to 363°K requires 2.5 hours.

The electrical energy consumption lies between 350 kw and 450 kw. At maximum heat load (40 kw), 20,120 kg/h of gas is circulated.

It is difficult to name a consumption figure for titanium sublimation pump because it is highly dependent upon the gas load. This load in turn is caused by leakage and outgasing from the shroud and the specimen; the order of magnitude of these quantities is difficult to establish. The maximum condensation rate is 14 grams per hour. Two kilograms of titanium are available in the ten melting crucibles, of which a maximum of 800 grams can be vaporized.

Specimen Handling

The configuration of the chamber requires that the test specimen be inserted from the top. For this purpose, the chamber lid with the upper shroud section is lifted. The specimen is installed with an adapter on a supporting framework (spider). This assembly is then lowered, using a lifting device, onto the three mounting posts. After the specimen is in place, the lifting device is removed. The chamber has also been modified so that the specimen can be suspended therein (Fig. 7).

Operational Practice

The test facility has been operated for 1500 hours without problems, and the personnel training time was only a few days.

Test results show, however, that the shroud absorption coefficient of about 90 % is insufficient for tests on the HELIOS thermal model. The reasons for this, and the correctional steps taken, will be explained in a separate presentation.

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Fig. 1
INFRARED-SIMULATION- AND THERMAL-VACUUM-FACILITY

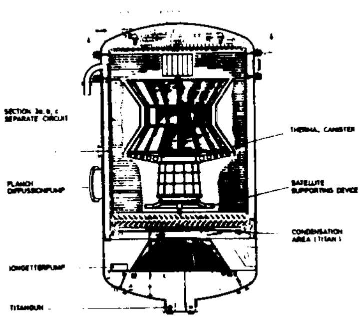


Fig.4 ISA/TVA SHROUD ELEMENTS

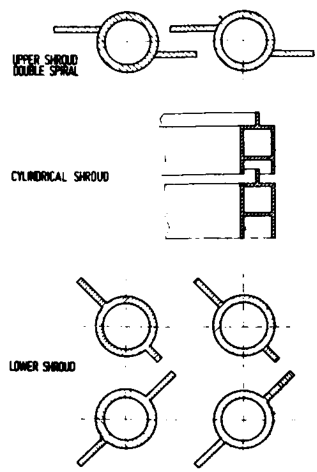


Fig.2 HELIOS REQUIREMENTS FOR TEST FACILITY

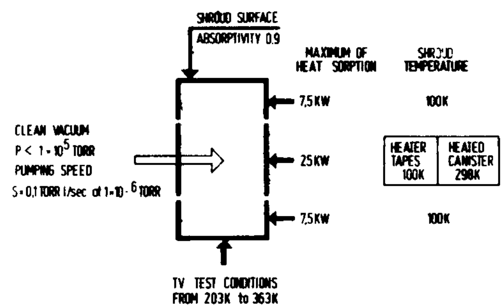
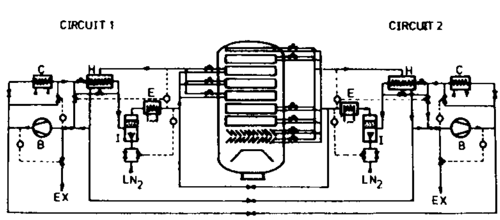


FIG.3 THERMAL SYSTEM



B	BLOWER	EX	EXHAUST
C	CHILLER H_2O COOLED	H	HEAT EXCHANGER
E	EL.HEATER	I	LN_2 INJECTION

FIG.5 ISA/TVA THERMAL SYSTEM CONTROL

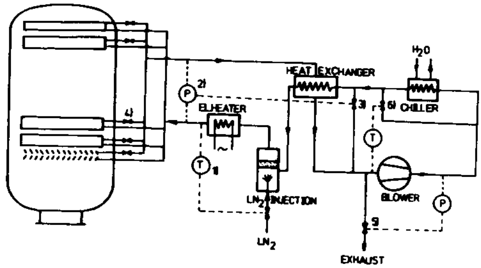


FIG.6 HIGH VACUUM SYSTEM

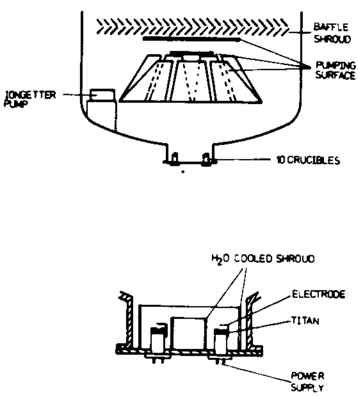


FIG.7 HANDLING OF THE SPACECRAFT